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fauna may have been contemporary with several successive marine faunae. At present our knowledge of the terrestrial faunae of past epochs is so slight that no practical difficulty arises from using, as we do, sea-reckoning for land time. But I think it is highly probable that sooner or later the inhabitants of the land will be found to have a history of their own."

When these words were written, more than twenty-four years ago, scarcely one of the geological details to which Mr. Blanford called attention was known. He need not point out how wonderful a commentary such details have afforded to Professor Huxley's views. But there is, he believed, an additional distinction between land and marine faunas, that requires notice. At the present day the difference between the land-faunas of different parts of the world is so vastly greater than that between the marine faunas, that if both were found fossilized, whilst there would be but little difficulty in recognizing different marine deposits as of like age from their organic remains, terrestrial and fresh-water beds would in all probability be referred to widely differing epochs.

Our present knowledge of the distribution of terrestrial and marine faunas and floras can be only briefly treated. Among mammals and reptiles, the marine forms are generally the most widely diffused. Fishes give better illustration: eighty families are typically marine, and twenty-nine are confined to fresh water; of the first, fifty are universally, or almost universally, distributed; while of the second, only one (Cyprinidae) is found in five of Wallace's regions, and not one is met with in all six. It is impossible to conceive a greater contrast. The distribution of land and sea Mollusca leads to a similar conclusion as to the relatively narrow range of the land forms. Throughout the marine invertebrata, but few generic types are restricted to particular seas: the majority are found in suitable habitats over a large portion of the oceans. Indeed, the marine provinces that have been hitherto distinguished are founded rather on specific than on generic distinctions. Botany offers a still more remarkable example: so uniform is the marine vegetation of the world, that no separate regions can be established in the ocean, while Drude makes fourteen on the land.

Mr. Blanford alluded to the evidence of the existence of land-regions in past times. Proofs are already accumulated of differences between the fauna of distant countries in tertiary times. The eocene, miocene, and pliocene Vertebrata of North America differ quite as much from those of Europe as do the genera of the present day; and there was as much distinction between the mammalia of the Himalayas and of Greece when the Siwalik and Pikermi faunas were living as there is now. The reptiles of the American Jurassic deposits present wide differences from those of the European beds of that age. But there is no reason for supposing that the limits or relations of the zoölogical and botanical regions in past times were the same as they now are. It is quite certain, indeed, that the distribution of land-areas has undergone enormous variations, whether the great oceanic tract

has remained unchanged in its general outlines or not; and the migration of the terrestrial fauna and flora must have been dependent upon the presence or absence of land communication between different continental tracts: in other words, the terrestrial regions of past epochs, although just as clearly marked as those of the present day, were very differently distributed.

The idea that marine and terrestrial faunas and floras were similar throughout the world's surface in past times, is so ingrained in paleontological science, that it will require many years yet before the fallacy of the assumption is generally admitted. No circumstance has contributed more widely to the belief than the supposed universal diffusion of the carboniferous flora. The evidence that the plants which prevailed in the coal-measures of Europe were replaced by totally different forms in Australia, despite the closest similarity in the marine inhabitants of the two areas at the period, will probably go far to give the death-blow to an hypothesis that rests upon no solid ground of observation. In a vast number of instances it has been assumed that similarity between fossil terrestrial faunas and floras proves identity of geological age; and by arguing in a vicious circle, the occurrence of similar types, assumed without sufficient proof to belong to the same geological period, has been alleged as evidence of the existence of similar forms in distant countries at the same time.

It may perhaps have surprised some, that Mr. Blanford scarcely alluded to any American formations, and especially that he had not mentioned so well-known and interesting a case of conflicting paleontological evidence as that of the Laramie group. His reason was simply, that there were probably many present who were personally acquainted with the geology of the American cretaceous and tertiary beds, and who were far better able to judge than he of the evidence as a whole. To all who are studying such questions in America, he thought it would be more useful to give the details of similar geological puzzles from the eastern hemisphere, than to attempt an imperfect analysis of difficult problems in the great western continent.

THE PHYSIOLOGY OF DEEP-SEA LIFE.¹

The physiology of the deep-sea life has, until lately, received but little attention from professed physiologists. No one has yet set forth the numerous difficulties which are encountered, when the attempt is made to comprehend the mode in which the ordinary physiological processes of Vertebrata and other animals are carried on under the peculiar physical conditions which exist at great depths.

A knowledge of the conditions under which gases occur in a state of absorption in the ocean-waters

¹ Abstract of an address to the biological section of the British association at Montreal, Aug. 28, 1884, by H. N. MOSELEY, Esq., M.A., F.R.S., Linacre professor of human and comparative anatomy in the University of Oxford, president of the section.

is of primary importance to the physiologist. It appears from the results of Professor Dittmar's researches into the composition of the ocean-water collected by the Challenger, that, contrary to what was before suspected, the presence of free carbonic acid in sea-water is an exception. Hence, with regard to Mr. Murray's interesting discovery, that, after certain depths are reached, pteropod shells are dissolved, and disappear from the sea-bottom, and at certain farther depths Globigerina shells suffer the same fate, Professor Dittmar holds that the solution is not due to the presence of free acid, but to the solvent action of the sea-water itself. Thus the amount of carbonic acid normally present throughout the ocean cannot be inimical to life; but there must be in the depths of the ocean numerous bodies of richly carbonated water.

French physiologists have lately commenced researches on some of the problems of deep-sea life. Experiments have been made by Mr. Regnard with a view of determining the effects of high pressures, corresponding with those of the deep sea, on various organisms. Yeast, after being exposed to a pressure of a thousand atmospheres, equal to a depth of about sixty-five hundred fathoms of sea-water, for an hour, was mixed with a solution of sugar. An hour elapsed before any signs of fermentation appeared; and a mixture of yeast and sugar solution did not ferment at all whilst under a pressure of six hundred atmospheres, equal to a depth of about thirty-nine hundred fathoms. Algae, seeds of phanerogamic plants, infusoria, and even Mollusca and leeches, were found to be thrown into a condition of sleep, or latency, by exposure to similar pressures, recovering from this condition after a shorter or longer period of return to normal conditions. A fish without a swimming-bladder, or one with the bladder emptied of air, may be submitted to a pressure of a hundred atmospheres, equivalent to a depth of six hundred and fifty fathoms, without injurious effect. At two hundred atmospheres, equivalent to a depth of thirteen hundred fathoms, it becomes torpid, but soon revives when the pressure is removed. At three hundred atmospheres, equivalent to a depth of about two thousand fathoms, the fish dies. These experiments are of the highest interest. The pressure made use of was obtained by means of water, in the absence of air other than that absorbed at the normal atmosphere pressure; and thus the physical conditions produced were closely similar to those actually existent in the deep sea. They are the first of their kind.

Professor Paul Bert's somewhat similar experiments related to a different question altogether; namely, the effect, on aquatic organisms, of water subjected to the pressure of compressed air. He found that young eels were rapidly killed when subjected to a pressure of only fifteen atmospheres, and could not survive one of even seven atmospheres for any considerable time. He pointed out the essential difference between the conditions produced in such experiments and those existing in the deep sea, where the charge of oxygen contained by the water has been

taken up at the surface under a pressure of one atmosphere only.

A question of the utmost moment, and one that has received a good deal of attention, is that as to the source of food of the deep-sea animals. Certainly a large proportion of this food is derived from the life on the ocean-surface. The *débris* of pelagic animals sinks slowly downwards, forming on its passage a sparsely scattered supply of food for any animals possibly living at intermediate depths, but becoming concentrated, as it were, on the bottom. A large part of the food-supply is also derived from the *débris* of the coasts, either directly from the littoral zone, or by rivers and the action of the tides from terrestrial life. Deep-sea life appears to diminish in abundance as coasts are receded from. Unfortunately, our knowledge of pelagic vegetable life is very imperfect, and it is to be hoped that botanists may be led to take up the subject. It will then be possible to form a nearer estimate of the extent to which plants are capable of forming a sufficient ultimate food-source for the greater part of the pelagic fauna, and, through it, of deep-sea life. The question is of importance; because, if the deep sea derived its main supply from the coasts and land-surfaces in the early history of the habitation of the globe by animals, there can have existed scarcely any deep-sea fauna until the littoral and terrestrial faunas and floras had become well established. It seems certain that the food, as it reaches the deep sea, is mostly in the form of dead matter; and it may be that the long but slender backward-directed teeth of many deep sea fish, resembling those of snakes, are used rather as aids for swallowing whole other fishes which have fallen from above, dead, and thus making the best of an occasional opportunity of a meal, than for catching and killing living prey.

Many interesting results may be expected when the histology of animals from great depths comes to be worked out, and especially that of the special sense-organs. At present very little has been attempted in this direction; principally, no doubt, because deep-sea specimens are too precious to be used for the purpose. With regard to the all-important question of the nature of the light undoubtedly present in the deep sea, it is hardly possible to accept Professor Verrill's recent startling suggestion (*Science*, iv. 8), that sunlight penetrates to the greatest depths with perhaps an intensity at from two thousand to three thousand fathoms, equal to that of some of our partially moonlight nights. Such a conjecture is entirely at variance with the results of all experiments on the penetration of sea-water by sunlight, as yet made by physicists,—results which have prevented other naturalists from adopting this solution of the problem.

The progress of research confirms the conclusions, early formed, that it is impossible to determine any successive zones of depth in the deep-sea regions, characterized by the presence of special groups of animals. Some groups of animals appear to be characteristic of water of considerable depth; but representatives of them struggle up into much shallower regions. There are numerous genera, and even spe-

cies, which range even from the shore-region to great depths. These facts add seriously to the difficulties encountered in the attempt to determine approximately the depths at which geological deposits have been found. Dr. Theodore Fuchs has attempted to determine what geological strata should be considered as of deep-sea formation; but, as he defines the deep-sea fauna as commencing at a hundred fathoms, and extending downwards to all depths, his results have little value as indicating the depths of ancient seas, or the extent of upheaval or depression of their bottoms. Mr. John Murray has shown that the depths at which modern deep-sea deposits have been formed can be approximately ascertained by the examination of their microscopical composition, and the condition of preservation of the shells and spicules.

The most important question with regard to life in the ocean, at present insufficiently answered, is that as to the conditions with regard to life of the intermediate waters between the surface and the bottom. The greatest uncertainty and difference of opinion exist as to whether the intermediate waters are inhabited at all by animals, and, if they are inhabited, to what extent; and these intermediate waters constitute by far the greater part of the ocean. Great care should be exercised in drawing conclusions from the depths ascribed to animals in some of the memoirs in the official work on the Challenger expedition. In many instances it is quite possible that a particular specimen may have entered the net at any depth.

With regard to the constitution of the deep-sea fauna, one of its most remarkable features is the general absence from it of paleozoic forms, excepting so far as representatives of the Mollusca and Brachiopoda are concerned; and it is remarkable, that, amongst the deep-sea Mollusca, no representatives of the Nautilidae and Ammonitidae, so excessively abundant in ancient periods, occur, and that Lingula, the most ancient brachiopod, should occur in shallow water only. It might well have been expected, that, had the deep sea been fully colonized in the paleozoic period, a considerable series of representative forms of that age might have survived there, in the absence of most of the active physical agents of modification which characterize the coast-regions.

With regard to the origin of the deep-sea fauna, there can be little doubt that it has been derived almost entirely from the littoral fauna, which also must have preceded, and possibly given rise to, the entire terrestrial fauna; yet it is not improbable that we should look to the pelagic conditions of existence as those under which most of the earliest types of animal life were developed. Nearly all the present inhabitants of the littoral zone revert to the pelagic free-swimming form of existence in their early developmental stages. And these pelagic larval forms are in many cases so closely alike in essential structure, though springing from parents widely differentiated from one another in the adult form, that it is impossible to regard them as otherwise than ancestral. The various early pelagic free-swimming forms, represented now mostly only by larvae, gradually adapted

themselves to coast-life, and underwent various modifications to enable them to withstand the beating of the surf on the shores, and the actual modifying alterations of the tides, which, together with other circumstances of coast-life, acted as strong impulses to their further development and differentiation. Some developed hard shells and skeletons as protections; others secured their position by boring in the rocks or mud; others assumed an attached condition, and thus resisted the wash of the waves.

It is because the ancestors of nearly all animals have passed through a littoral phase of existence, preceded mostly by a pelagic phase, that the investigations now being carried on, on the coasts in marine laboratories, throw floods of light on all the fundamental problems of zoölogy. From the littoral fauna a gradual migration must have taken place into the deep sea; but probably this did not occur till the littoral fauna was very fully established, and considerable pressure was brought to bear on it by the struggle for existence. Life, too, must have become abundant in the littoral zone before there could have been a sufficient food-supply in the deeper regions adjoining it. Not until the development of terrestrial vegetation and animal life can the supply have reached its present abundance. Such a condition was, however, certainly reached in the carboniferous period. From the general absence of representatives of paleozoic forms from the deep sea, it is just possible, that, if deep oceans existed in paleozoic periods, they may not have been colonized at all, and that active migration into deep waters commenced in the secondary period. Very possibly the discharges of carbonic acid from the interior of the earth, which Professor Dittmar believes may have been sufficient to account for the vast existing deposits of coal and limestone, may have been much more abundant over the deep-sea beds in the paleozoic period, than at present, and have rendered the deep waters more or less uninhabitable.

RECENT GEOGRAPHICAL DISCOVERY.¹

AFTER some introductory remarks referring to his previous visit to Canada, Gen. Lefroy alluded to the relations of geography to geology as instanced in the changes in the earth's surface within historical times by the operation of geological causes. A recent German writer, Dr. Hahn, has enumerated ninety-six more or less extensive tracts known to be rising or sinking. For example: Mr. R. A. Peacock has accumulated evidence that the Island of Jersey had no existence in Ptolemy's time, and Mr. A. Howarth has collected similar proofs with regard to the arctic regions; and every fresh discovery, notably those of the gallant and ill-fated DeLong and of Nordenskiöld, adds to the number. Professor Hull has reached the conclusion that the land between Suez and the

¹ Address to the geographical section of the British association at Montreal, Aug. 28, 1884, by Gen. Sir J. H. LEFROY, R.A., C.B., K.C.M.G., F.R.S., F.S.A., vice-president of the Royal geographical society, president of the section.